US009458742B2

(12) **United States Patent**
Suzuki

(10) **Patent No.: US 9,458,742 B2**
(45) **Date of Patent: Oct. 4, 2016**

(54) **VARIABLE VALVE MECHANISM FOR INTERNAL COMBUSTION ENGINE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/794,146**

(22) Filed: **Jul. 8, 2015**

(65) **Prior Publication Data**

US 2016/0017769 A1 Jan. 21, 2016

(30) **Foreign Application Priority Data**

Jul. 16, 2014 (JP) 2014-145640

(51) **Int. Cl.**

F01L 1/34	(2006.01)
F01L 1/344	(2006.01)
F01L 1/08	(2006.01)
F01L 1/26	(2006.01)
F01L 13/00	(2006.01)
F01L 1/047	(2006.01)

(52) **U.S. Cl.**

CPC ***F01L 1/344*** (2013.01); ***F01L 1/047*** (2013.01); ***F01L 1/08*** (2013.01); ***F01L 1/267*** (2013.01); ***F01L 13/0031*** (2013.01); ***F01L 13/0063*** (2013.01)

(58) **Field of Classification Search**

CPC F01L 1/08; F01L 1/047; F01L 1/267; F01L 1/344; F01L 13/0063

USPC 123/90.16, 90.18, 90.6

See application file for complete search history.

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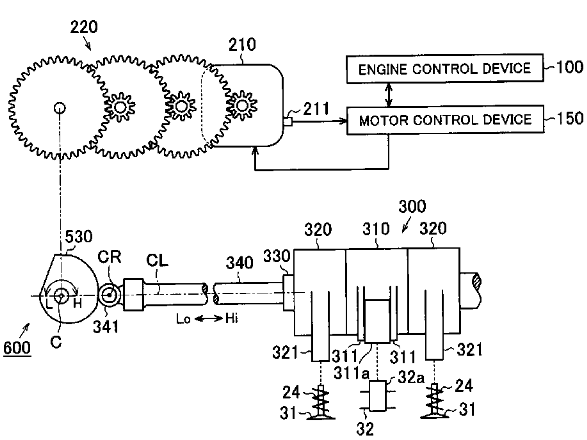
(57) **ABSTRACT**

A variable valve mechanism for an internal combustion engine includes a control shaft and a cam. The control shaft is configured to change a maximum lift amount of an engine valve according to displacement of the control shaft. The cam is configured to displace the control shaft in the axial direction due to rotation of the cam. The cam surface includes change zones and retention zones. Respective lengths of the retention zones in a rotation direction of the cam is set such that respective length of the retention zones in the rotation direction increases as the maximum lift amount retained by the retention zones increases.

4 Claims, 8 Drawing Sheets



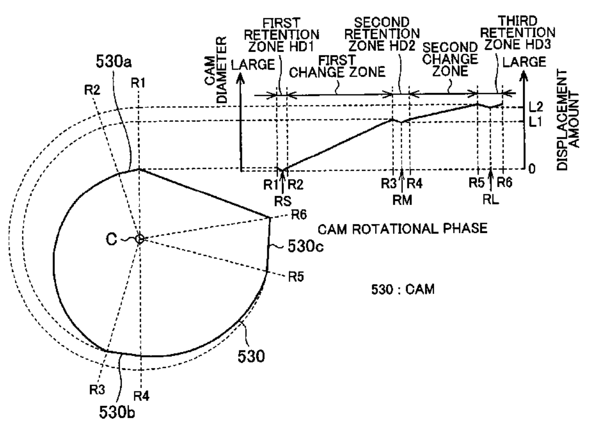
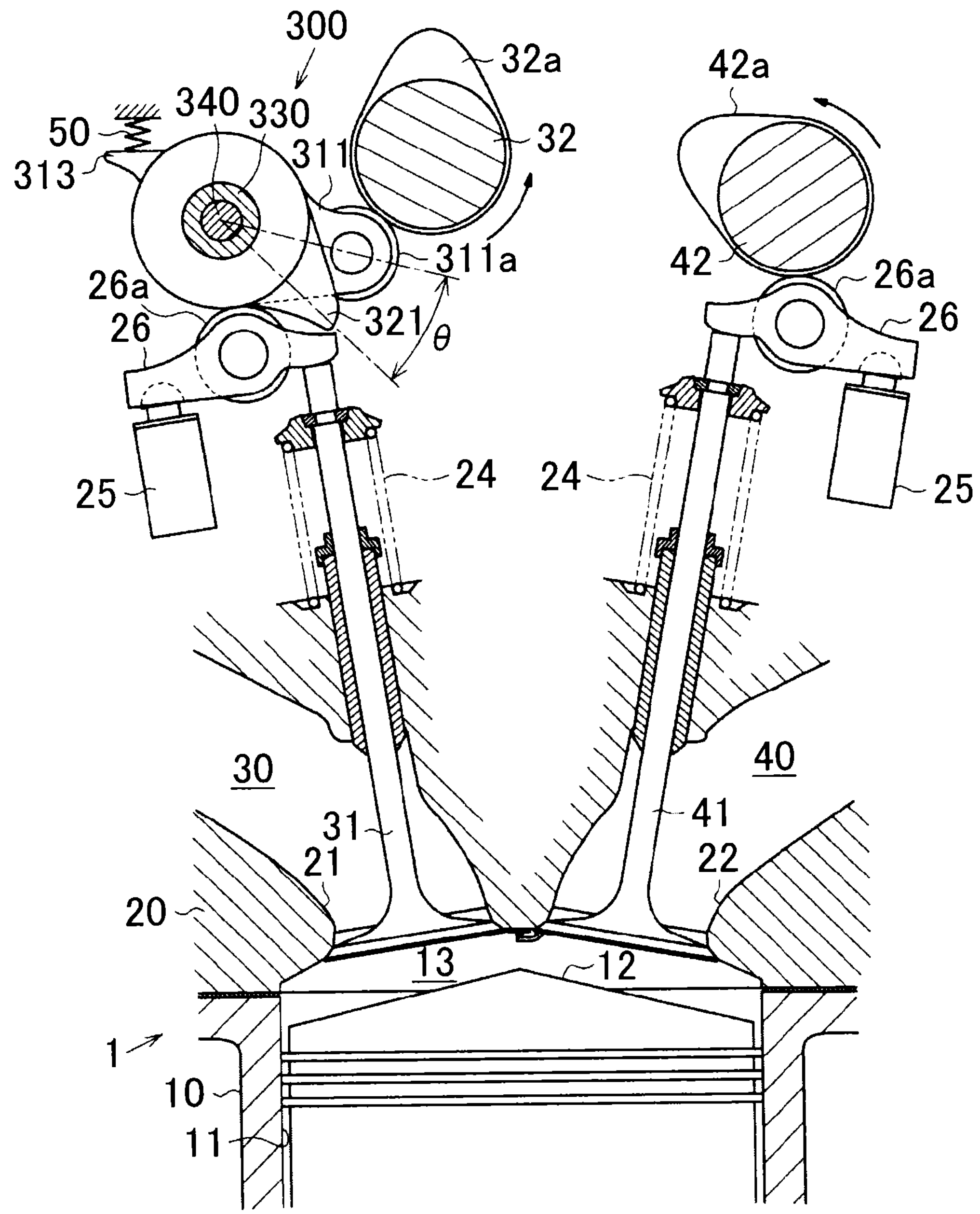


FIG. 1


300
32a
42a
340
330
50
311
32
313
311a
42
26a
26a
321
26
26
θ
24
24
25
25
30
40
31
41
21
22
20
13
12
1
10
11

F I G . 2

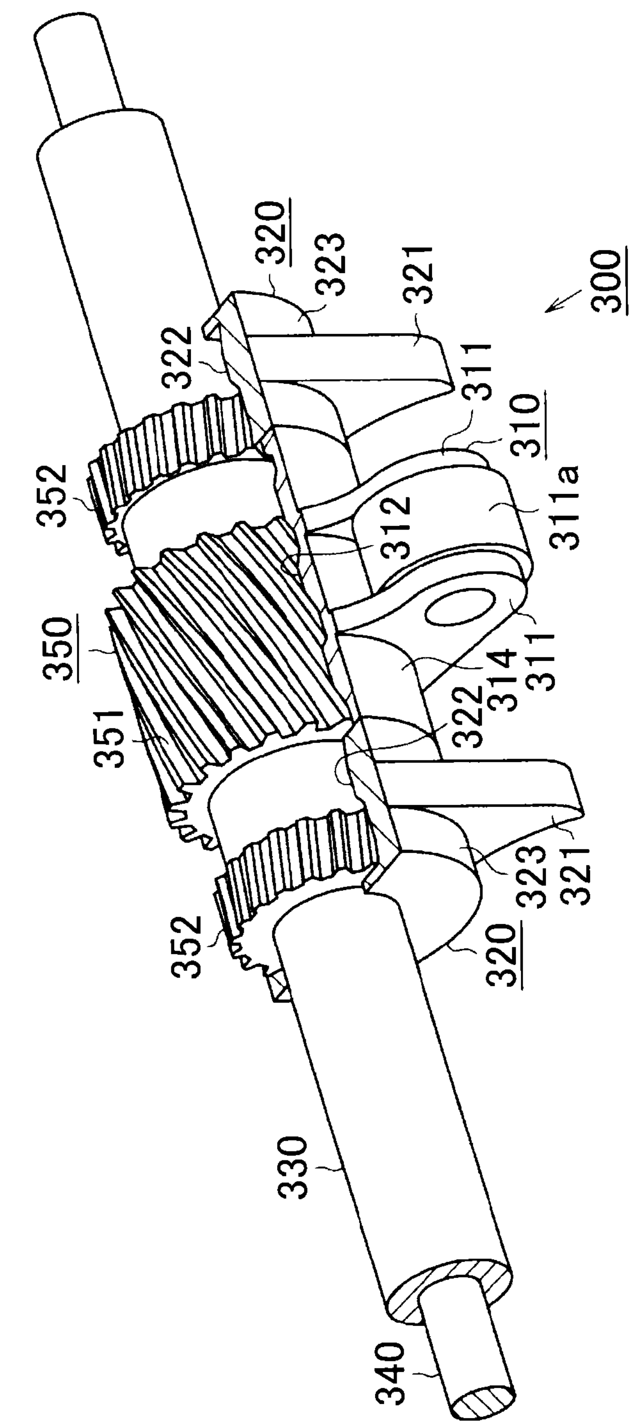
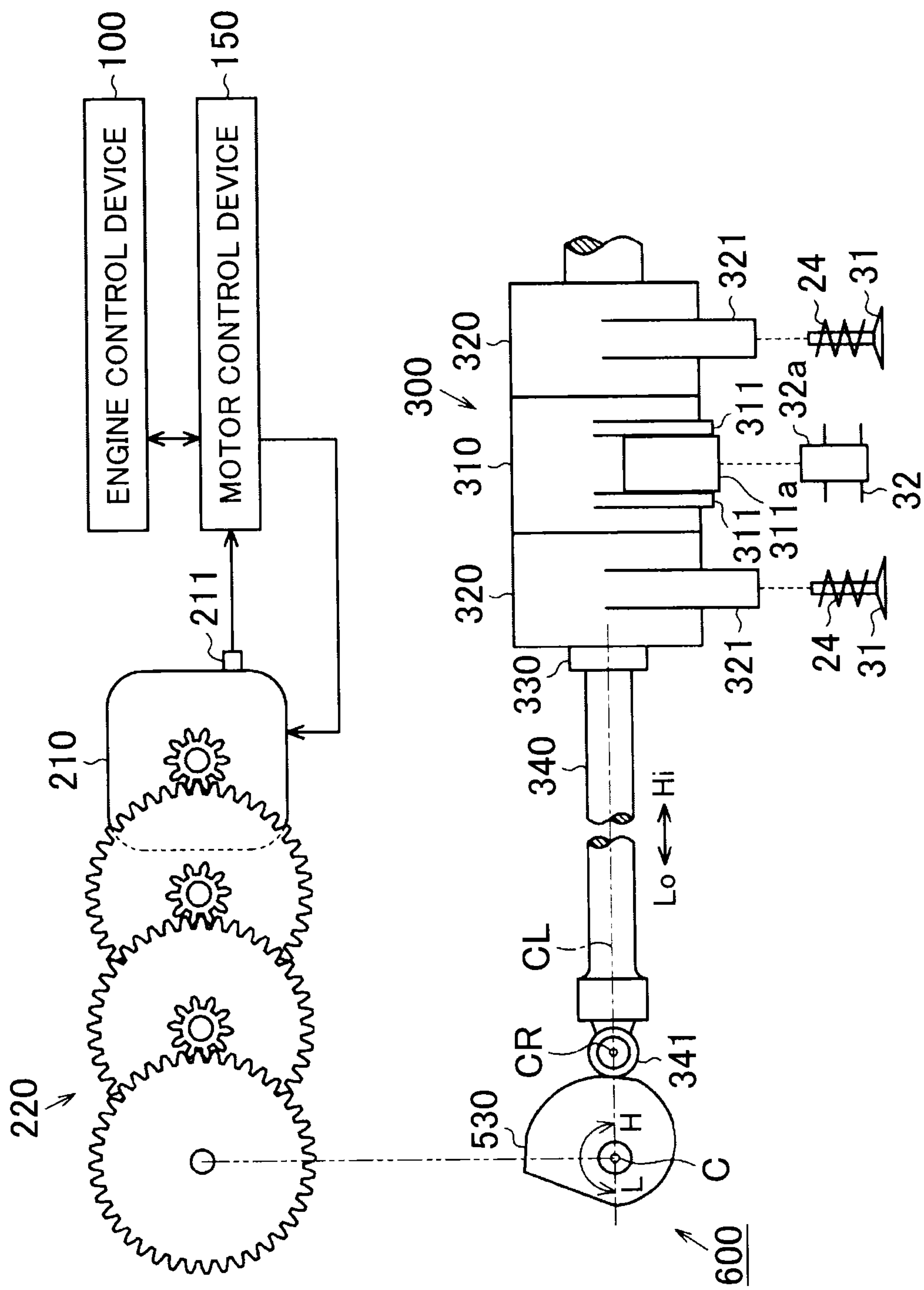

300
320
323
321
322
311
310
311a
312
352
350
351
314
311
322
323
321
320
352
330
340

FIG. 3



ENGINE CONTROL DEVICE
100
MOTOR CONTROL DEVICE
150
211
210
220
300
310
311
311
311a
320
320
321
321
24
24
31
31
32a
32
330
340
Lo
Hi
CL
CR
341
530
H
L
C
600

FIG. 4

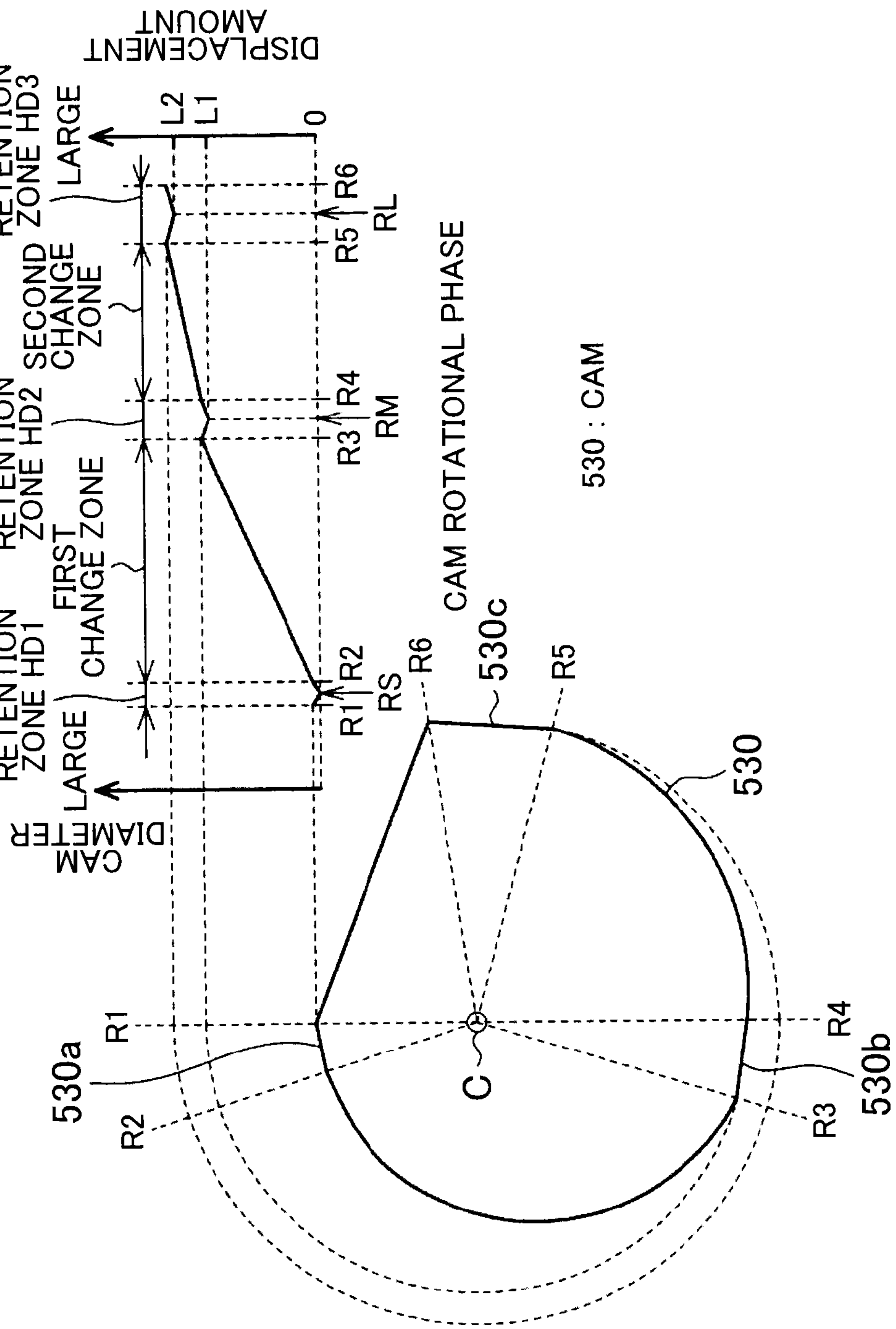
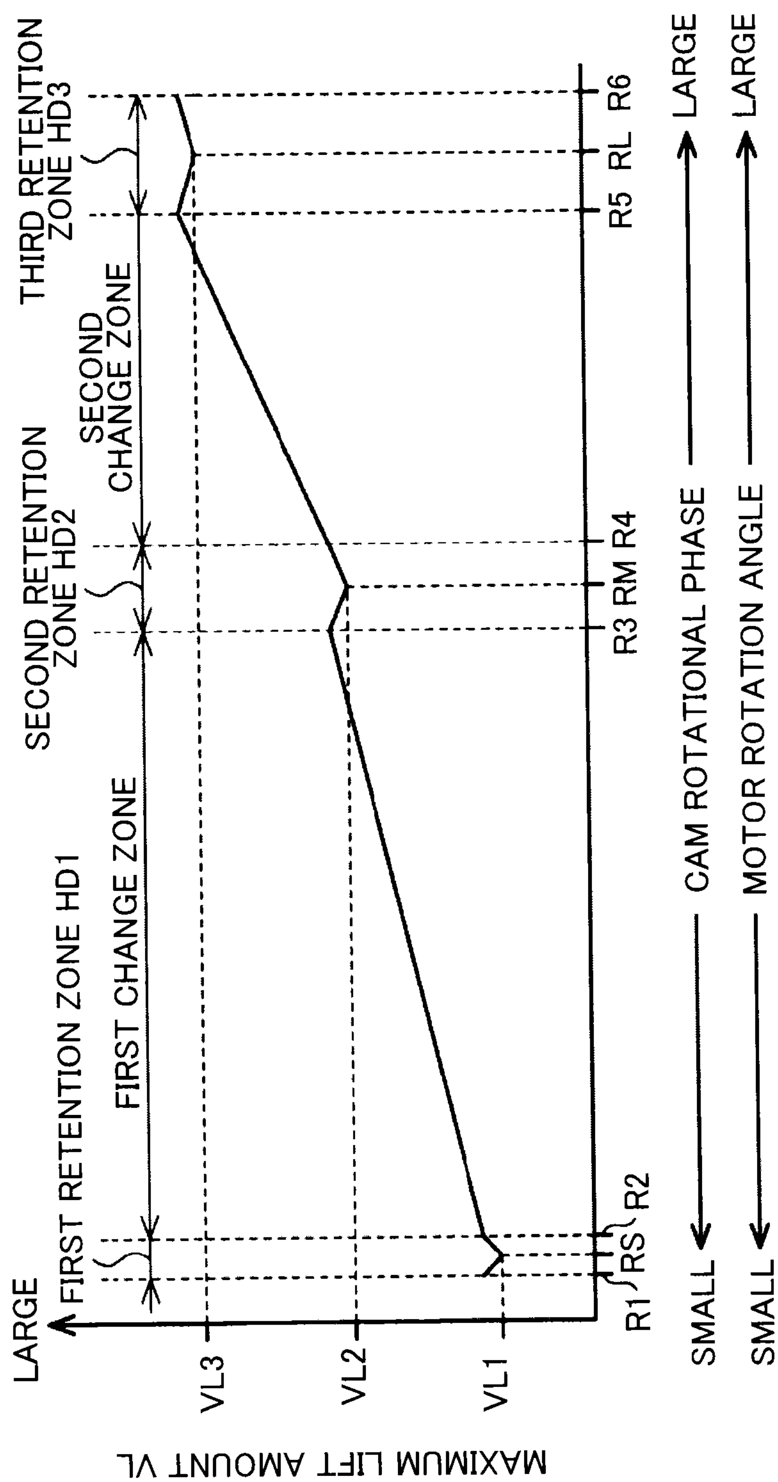

DISPLACEMENT AMOUNT
CAM DIAMETER
LARGE
LARGE
L2
L1
0
THIRD RETENTION ZONE HD3
SECOND CHANGE ZONE
SECOND RETENTION ZONE HD2
FIRST CHANGE ZONE
FIRST RETENTION ZONE HD1
R1
R2
R3
R4
R5
R6
RS
RM
RL
CAM ROTATIONAL PHASE
530 : CAM
530
530a
530b
530c
C

FIG. 5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SECOND CHANGE ZONE
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FIRST RETENTION ZONE HD1
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VL3
VL2
VL1
MAXIMUM LIFT AMOUNT VL
R1
RS
R2
R3 RM R4
R5 RL R6
SMALL
CAM ROTATIONAL PHASE
LARGE
SMALL
MOTOR ROTATION ANGLE
LARGE

FIG. 6

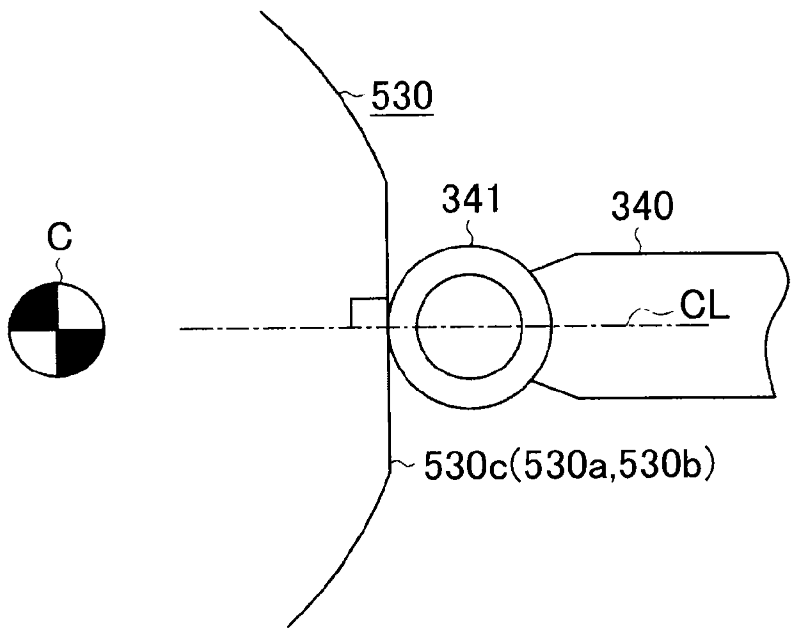
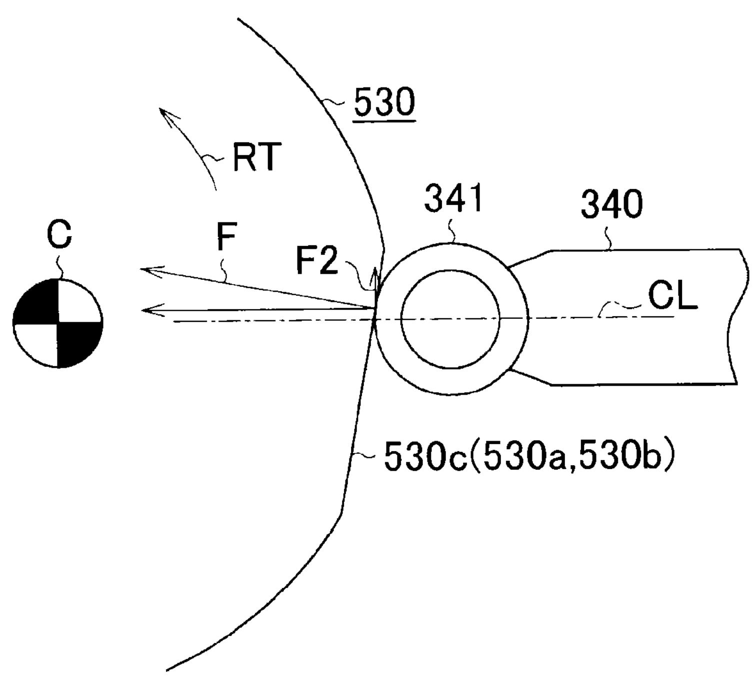

530
341
340
C
CL
530c(530a,530b)

FIG. 7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RT
341
340
C
F
F2
CL
530c(530a,530b)

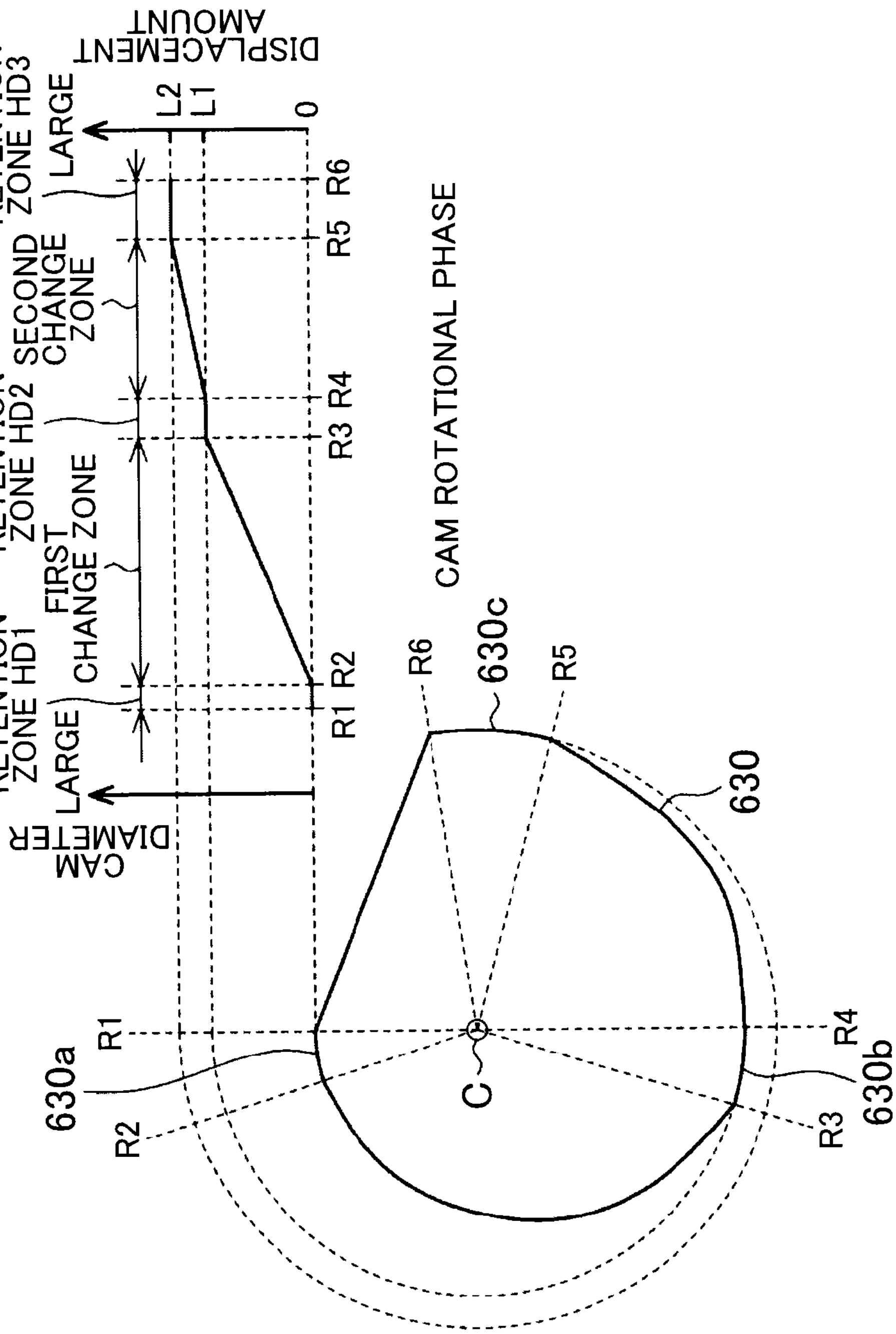

DISPLACEMENT AMOUNT
LARGE
L2
L1
0
THIRD RETENTION ZONE HD3
SECOND CHANGE ZONE
SECOND RETENTION ZONE HD2
FIRST CHANGE ZONE
FIRST RETENTION ZONE HD1
R1 R2 R3 R4 R5 R6
CAM ROTATIONAL PHASE
CAM DIAMETER
LARGE
630c
630
630a
630b
C
R1
R2
R3
R4
R5
R6

FIG. 8

FIG. 9

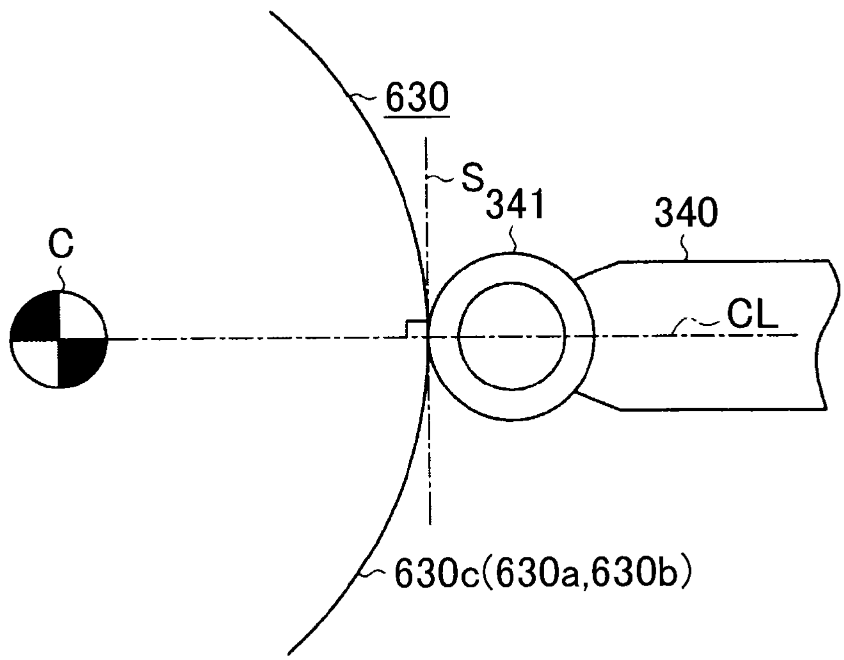
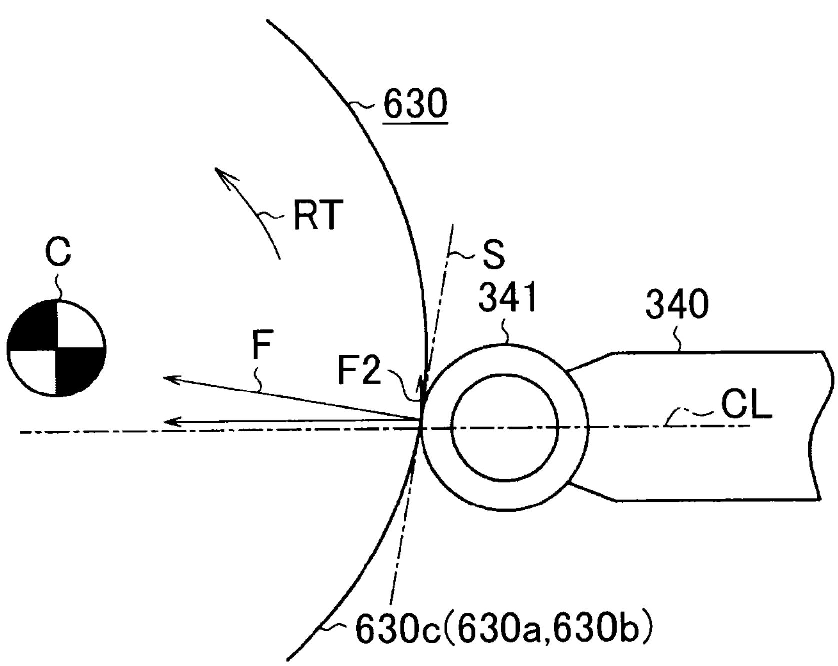

630
S
341
340
C
CL
630c(630a,630b)

FIG. 10


630
RT
S
341
340
C
F
F2
CL
630c(630a,630b)

VARIABLE VALVE MECHANISM FOR INTERNAL COMBUSTION ENGINE

INCORPORATION BY REFERENCE

The disclosure of Japanese Patent Application No. 2014-145640 filed on Jul. 16, 2014 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a variable valve mechanism for an internal combustion engine.

2. Description of Related Art

There has been known a variable valve mechanism that changes a maximum lift amount of an intake valve, which is one of engine valves, according to an engine operation state, as described in Japanese Patent Application Publication No. 2004-339951 (JP 2004-339951 A), for example. The variable valve mechanism described in JP 2004-339951 A includes: a control shaft that changes a maximum lift amount of the intake valve according to displacement in an axial direction; a cam that abuts with the control shaft and rotates the control shaft so as to displace the control shaft in the axial direction; a motor that pivots the cam, and the like. The maximum lift amount is changed by changing a rotational phase of the cam so as to change a displacement amount of the control shaft in the axial direction. In a cam surface of the cam, a change zone in which the maximum lift amount changes due to changes in the displacement amount of the control shaft, and a retention zone in which the displacement amount of the control shaft is constant and the maximum lift amount is retained at a constant value are formed. In the variable valve mechanism, the maximum lift amount is changed by changing the displacement amount of the control shaft by use of the cam surface in the change zone. Meanwhile, by retaining the displacement amount of the control shaft at a constant value by use of the cam surface in the retention zone, the maximum lift amount is retained at a constant value even when current application to the motor is stopped. Further, as such a retention zone, a plurality of retention zones in which to retain different maximum lift amounts is provided, thereby making it possible to retain the different maximum lift amounts.

SUMMARY OF THE INVENTION

A force in the axial direction (hereinafter referred to as an axial force) caused due to a reaction force of a valve spring that biases the engine valve is applied to the control shaft. The axial force is also transmitted to the cam via the control shaft. A magnitude of the axial force periodically changes according to changes in a compression amount of the valve spring along with opening/closing operations of the engine valve. Further, as the compression amount of the valve spring is larger, that is, as the maximum lift amount is larger, a maximum value of the axial force becomes larger.

Here, when the maximum lift amount is retained by use of the cam surface in the retention zone, a running torque caused due to the axial force may act on the cam. In this case, a magnitude of the running torque also periodically changes in accordance with periodic changes of the axial force. As a result, the cam swings according to such periodic changes of the running torque. Further, such a swing amount of the cam increases as a retained maximum lift amount is larger and the axial force is hereby larger. Accordingly, the swing amount of the cam might increase excessively depending on a magnitude of the retained maximum lift amount. In some cases, the control shaft that should abut with the cam surface in the retention zone might deviate from the retention zone and abut with the cam surface in the change zone.

When the control shaft deviates from the retention zone of the cam as such, it is difficult to obtain an effect to retain the maximum lift amount by use of the retention zone, for example, that is, an effect to be able to retain the maximum lift amount at a constant value even if current application to the motor is stopped as described above. This accordingly causes inconvenience that power consumption of the motor increases, and so on.

The present invention provides a variable valve mechanism for an internal combustion engine which variable valve mechanism restrains an abutment portion between a control shaft and a cam from deviating from a retention zone provided in the cam at the time when a maximum lift amount is retained by use of the retention zone.

A variable valve mechanism for an internal combustion engine according to one aspect of the present invention includes a control shaft and a cam. The control shaft is configured to be displaced in an axial direction of the control shaft. The control shaft is configured to change a maximum lift amount of an engine valve of the internal combustion engine according to displacement of the control shaft. The cam includes a cam surface of the cam. The cam surface is configured to abut with the control shaft. The cam is configured to displace the control shaft in the axial direction due to rotation of the cam. The cam surface includes change zones and retention zones. The cam surface in the change zones is configured to change the maximum lift amount along with the rotation of the cam. The cam surface in the retention zones is configured to retain the maximum lift amount along with the rotation of the cam. Respective lengths of the retention zones in a rotation direction of the cam are set such that respective length of the retention zones in the rotation direction increases as the maximum lift amount retained by the retention zones increases.

In the variable valve mechanism according to the above aspect, the retention zone with a larger maximum lift amount to be retained, that is, the retention zone in which a swing amount at the time when the cam swings due to an axial force transmitted from the control shaft easily increases has a longer length in a rotation direction of the cam. Accordingly, even if the swing amount of the cam becomes large, an abutment portion between the control shaft and the cam is hard to deviate from the retention zone.

In the meantime, when the retention zone is set to be long, a necessary rotational phase amount of the cam to change the abutment portion between the control shaft and the cam from the retention zone to the change zone becomes large. Accordingly, a change velocity to change the maximum lift amount decreases. In this regard, in the above configuration, a retention zone with a larger maximum lift amount to be retained is set to have a longer length, whereas a retention zone with a smaller maximum lift amount to be retained is set to have a shorter length. Accordingly, in comparison with a case where all the retention zones are set to have sufficiently long lengths in accordance with a maximum value of the swing amount of the cam, the retention zone with a smaller maximum lift amount to be retained has a smaller necessary rotational phase amount of the cam to change the abutment portion from the retention zone to the change zone.

Accordingly, it is possible to appropriately restrain a decrease in a change velocity to change the maximum lift amount.

In the variable valve mechanism according to the above aspect, in the cam surface, the retention zones may be provided so as to be adjacent to the change zones. According to the above aspect, the maximum lift amount changed by use of the change zone can be retained in the retention zone adjacent to the change zone.

In the variable valve mechanism according to the above aspect, the cam surface in the change zones may be configured such that a cam diameter of the cam continuously increases along with the rotation of the cam such that the maximum lift amount increases along with the rotation of the cam. The cam surface in the retention zones may be a flat surface.

According to the above aspect, since the maximum lift amount changes continuously in the change zones, sudden changes in an intake-air amount along with changes of the maximum lift amount can be restrained. Accordingly, sudden changes in engine power torque or the like due to the sudden changes in the intake-air amount can be restrained, for example.

Further, the cam surface in the retention zones is formed to be a flat surface. Accordingly, a cam shape in the retention zones is a shape in which the cam diameter gradually increases after the cam diameter gradually decreases as the rotational phase of the cam changes in one direction, that is, a shape having a minimum point about the cam diameter. In such a cam shape having a minimum point, when the control shaft deviates from the cam surface at the minimum point, a component force of the axial force acts to return the rotational phase of the cam back to the minimum point. Due to the action of the component force, when the control shaft makes contact with the cam surface in the retention zone, the rotational phase of the cam is naturally directed toward the minimum point in the retention zone, so that the maximum lift amount is retained at an amount according to the cam diameter at the minimum point. Thus, according to the configuration, with such a simple structure in which the cam includes a cam surface in which the cam diameter continuously changes and the cam surface formed to be a flat surface, it is possible to embody change and retention of the maximum lift amount.

In the variable valve mechanism according to the above aspect, the cam surface in the change zones may be configured such that a cam diameter of the cam continuously increases along with the rotation of the cam such that the maximum lift amount increases along with the rotation of the cam. The cam surface in the retention zone may be configured such that the cam diameter is constant.

In the variable valve mechanism according to the above aspect, since the maximum lift amount changes continuously in the change zones, sudden changes in an intake-air amount along with changes in the maximum lift amount can be restrained. Accordingly, sudden changes in engine power torque or the like due to the sudden changes in the intake-air amount can be restrained, for example.

Further, since the cam diameter in the retention zone is formed so as to be constant, the displacement amount of the control shaft does not change in the retention zone. Accordingly, the maximum lift amount in the retention zone is retained at an amount according to the cam diameter thus formed to be constant. Thus, according to the configuration, with such a simple structure in which the cam includes a cam surface in which the cam diameter continuously changes and a cam surface formed so that the cam diameter is constant, it is possible to embody change and retention of the maximum lift amount.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. **1** is a sectional view illustrating a structure around a cylinder head of an internal combustion engine to which one embodiment of a variable valve mechanism is applied;

FIG. **2** is a cutaway perspective view of a variable mechanism portion;

FIG. **3** is a schematic view of the variable valve mechanism;

FIG. **4** is a view illustrating a profile and a cam diagram of a cam provided in the variable valve mechanism;

FIG. **5** is a graph illustrating a change mode of a maximum lift amount by the variable valve mechanism;

FIG. **6** is a magnified view illustrating a state where a control shaft abuts with a retention zone of the cam;

FIG. **7** is a magnified view illustrating a state where a control shaft abuts with the retention zone of the cam;

FIG. **8** is a view illustrating a profile and a cam diagram of a cam in another embodiment;

FIG. **9** is a magnified view illustrating a state where a control shaft abuts with a retention zone of a cam in another embodiment; and

FIG. **10** is a magnified view illustrating a state where a control shaft abuts with a retention zone of a cam in another embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

One embodiment of a variable valve mechanism for an internal combustion engine is described below with reference to FIGS. **1** to **7**. As illustrated in FIG. **1**, an internal combustion engine **1** includes a cylinder block **10** and a cylinder head **20** provided on the cylinder block **10**.

Cylindrical cylinders **11** according to the number of cylinders are formed inside the cylinder block **10**, and a piston **12** is slidably accommodated in each of the cylinders **11**. The cylinder head **20** is assembled to an upper side of the cylinder block **10**, and a combustion chamber **13** is formed to be sectioned by an inner peripheral surface of the cylinder **11**, a top face of the piston **12**, and a bottom face of the cylinder head **20**.

The cylinder head **20** is provided with an inlet port **21** communicating with an intake passage **30** and the combustion chamber **13**, and an exhaust port **22** communicating with an exhaust passage **40** and the combustion chamber **13**. The intake passage **30** is provided with a throttle valve driven by an actuator.

The inlet port **21** is provided with an intake valve **31** as an engine valve for communicating the combustion chamber **13** with the inlet port **21** and disconnecting the combustion chamber **13** from the inlet port **21**. The exhaust port **22** is provided with an exhaust valve **41** as an engine valve for communicating the combustion chamber **13** with the exhaust port **22** and disconnecting the combustion chamber **13** from the exhaust port **22**. The intake valve **31** and the exhaust valve **41** are biased by valve springs **24** in a valve closing direction.

Further, a lash adjuster **25** is provided inside the cylinder head **20** so as to correspond to each of the valves **31**, **41**. A rocker arm **26** is provided between the lash adjuster **25** and the each of the valves **31**, **41**. One end of the rocker arm **26** is supported by the lash adjuster **25**, and the other end thereof abuts with an end part of the each of the valves **31**, **41**.

Further, an intake camshaft **32** and an exhaust camshaft **42** for driving the valves **31**, **41**, respectively, are rotatably supported in the cylinder head **20**. An intake cam **32***a* is formed in the intake camshaft **32**, and an exhaust cam **42***a* is formed in the exhaust camshaft **42**. A roller **26***a* of the rocker arm **26** abutting with the exhaust valve **41** abuts with an outer peripheral surface of the exhaust cam **42***a*. Hereby, when the exhaust camshaft **42** rotates during an engine operation, the rocker arm **26** swings, due to action of the exhaust cam **42***a*, with a part supported by the lash adjuster **25** being taken as a fulcrum. Due to the swing of the rocker arm **26**, the exhaust valve **41** is opened and closed.

In the meantime, a variable mechanism portion **300** for changing valve characteristics of the intake valve **31** is provided between the rocker arm **26** abutting with the intake valve **31** and the intake cam **32***a*, and the variable mechanism portion **300** is provided for each cylinder. The variable mechanism portion **300** constitutes part of a variable valve mechanism **600**, and includes an input arm **311** and an output arm **321**. The input arm **311** and the output arm **321** are swingably supported around a support pipe **330** fixed to the cylinder head **20**. The rocker arm **26** is biased toward an output-arm-**321** side by a biasing force of the valve spring **24**, so that a roller **26***a* provided in an intermediate part of the rocker arm **26** abuts with an outer peripheral surface of the output arm **321**.

Further, a projection **313** is provided on an outer peripheral surface of the variable mechanism portion **300**, and a biasing force of a spring **50** fixed inside the cylinder head **20** acts on the projection **313**. Due to the biasing force of the spring **50**, a roller **311***a* provided in a tip end of the input arm **311** abuts with an outer peripheral surface of the intake cam **32***a*. Hereby, when the intake camshaft **32** rotates during an engine operation, the variable mechanism portion **300** swings around the support pipe **330** due to action of the intake cam **32***a*. Then, the rocker arm **26** is pressed by the output arm **321**, so that the rocker arm **26** swings with a part supported by the lash adjuster **25** being taken as a fulcrum. Due to the swing of the rocker arm **26**, the intake valve **31** is opened and closed.

A control shaft **340** movable along an axial direction of the support pipe **330** is inserted into the support pipe **330**. The variable mechanism portion **300** displaces the control shaft **340** in the axial direction, so as to change a relative phase difference between the input arm **311** and the output arm **321** around the support pipe **330**, namely, an angle θ shown in FIG. **1**.

Referring now to FIG. **2**, a configuration of the variable mechanism portion **300** is described below further in detail. As illustrated in FIG. **2**, output portions **320** are provided in the variable mechanism portion **300** across an input portion **310** such that the output portions **320** are disposed on both sides of the input portion **310**.

A housing **314** of the input portion **310** and housings **323** of the output portions **320** are each formed in a hollow cylinder shape, and the support pipe **330** is passed through the housings **314**, **323**.

Helical splines **312** are formed on an inner periphery of the housing **314** of the input portion **310**. In the meantime, helical splines **322** with flank lines along a direction opposite to the helical splines **312** of the input portion **310** are formed on an inner periphery of the housing **323** of each of the output portions **320**.

A slider gear **350** is disposed in a consecutive internal space formed by respective housings **314**, **323** of the input portion **310** and two output portions **320**. The slider gear **350** is formed in a hollow cylindrical shape, and is disposed on an outer peripheral surface of the support pipe **330** in a reciprocating manner along an axial direction of the support pipe **330** and in a relatively rotatable manner around an axis of the support pipe **330**.

Helical splines **351** meshed with the helical splines **312** of the input portion **310** are formed on an outer peripheral surface of an axially central part of the slider gear **350**. In the meantime, helical splines **352** meshed with the helical splines **322** of the output portions **320** are formed on respective outer peripheral surfaces of both axially end parts of the slider gear **350**.

A control shaft **340** movable along the axial direction of the support pipe **330** is provided inside the support pipe **330**. The control shaft **340** is engaged with the slider gear **350** with a pin, and the slider gear **350** can pivot relative to the support pipe **330** and also moves along the axial direction association with axial movement of the control shaft **340**.

In the variable mechanism portion **300** configured as such, when the control shaft **340** moves in the axial direction, the slider gear **350** also moves in the axial direction in association with the movement of the control shaft **340**. The helical splines **351**, **352** formed on the outer peripheral surface of the slider gear **350** have flank lines along different formation directions, and are meshed with respective helical splines **312**, **322** formed on the inner peripheral surfaces of the input portion **310** and the output portion **320**. Accordingly, when the slider gear **350** moves in the axial direction, the input portion **310** and the output portion **320** pivot in opposite directions. As a result, a relative phase difference between the input arm **311** and the output arm **321** is changed, so that a maximum lift amount and a valve opening period, which are valve characteristics of the intake valve **31**, are changed. More specifically, when the control shaft **340** is moved in a direction where the maximum lift amount increases, the slider gear **350** is also moved in the same direction together with the control shaft **340**. In association with this, the relative phase difference between the input arm **311** and the output arm **321**, that is, the angle θ shown in FIG. **1** increases, so that a maximum lift amount VL and a valve opening period of the intake valve **31** increase, thereby increasing an intake-air volume. In the meantime, when the control shaft **340** is moved in a direction where the maximum lift amount decreases, the slider gear **350** is also moved in the same direction together with the control shaft **340**, so that the relative phase difference between the input arm **311** and the output arm **321**, that is, the angle θ shown in FIG. **1** decreases. Hereby, the maximum lift amount VL and the valve opening period of the intake valve **31** both decrease, so that the intake-air amount decreases.

Next will be described a configuration of a driving portion for moving the control shaft **340** of the variable valve mechanism **600** in the axial direction. As illustrated in FIG. **3**, the driving portion of the variable valve mechanism **600** includes: a motor **210**; a deceleration mechanism **220** for decreasing a rotation speed of the motor **210**; a cam **530** with which a roller **341** provided in an end part of the control shaft **340** abuts; and the like.

A rotation center CR of the roller **341** and a rotation center C of the cam **530** are disposed on an extended line of a central axis CL of the control shaft **340**. The motor **210** is a duty-driven electric motor, and the motor **210** is provided with a rotation angle sensor **211** for detecting a rotation angle.

The deceleration mechanism **220** includes a plurality of gears meshed with each other. An input shaft of the deceleration mechanism **220** is connected to an output shaft of the motor **210**, and an output shaft of the deceleration mechanism **220** is connected to a central shaft of the cam **530**. When the cam **530** pivots, the control shaft **340** is displaced in an axial direction, which is a direction in which a central axis of the control shaft **340** extends, along with changes in a cam diameter (a distance from a rotation center of the cam to a cam surface).

A motor control device **150** for controlling driving of the motor **210** is connected to the motor **210**. A rotation angle of the motor **210** is controlled in response to a driving signal from the motor control device **150**. The motor control device **150** is connected to an engine control device **100** for controlling an operation state of the internal combustion engine **1**.

An accelerator operation amount detected by an accelerator operation amount sensor, a crank angle detected by a crank angle sensor, an opening degree (a throttle opening degree TA) of a throttle valve which opening degree is detected by an opening degree sensor, an intake-air amount GA detected by an air-flow meter and the like are input to the engine control device **100**. Then, the engine control device **100** calculates a target air amount GAp, which is a target value of an intake-air amount according to an engine operation state, based on an engine rotation speed NE calculated from the crank angle, the accelerator operation amount ACCP, and the like, for example, and calculates a combination of the throttle opening degree and that maximum lift amount of the intake valve **31** which is obtained from the target air amount GAp. Then, the maximum lift amount thus calculated is set as a target lift amount VLp, and the throttle opening degree thus calculated is set as a target throttle opening degree TAp. When the target lift amount VLp is set as such, a target rotational phase Kp of the cam **530** corresponding to the target lift amount VLp is calculated in the motor control device **150**, and a rotation angle of the motor **210** is feedback-controlled so that a rotational phase of the cam **530** reaches the target rotational phase Kp thus calculated. Further, when the target throttle opening degree TAp is set, the engine control device **100** drive-controls the actuator of the throttle valve so that an actual throttle opening degree TA accords with the target throttle opening degree TAp.

Further, the motor control device **150** calculates an actual rotational phase K of the cam **530** from that rotation angle of the motor **210** which is detected by the rotation angle sensor **211**, and then calculates a current value of the maximum lift amount VL from the rotational phase K thus calculated. Then, the motor control device **150** transmits the calculated current value of the maximum lift amount VL to the engine control device **100**.

Referring now to FIGS. **4** and **5**, the cam **530** for displacing the control shaft **340** is described below. A cam diagram illustrating a relationship between a rotational phase of the cam **530** and a displacement amount of the control shaft **340** is illustrated on a right side in FIG. **4**, and a cam profile (an actual shape of the cam **530**) formed based on the cam diagram is illustrated on a left side in FIG. **4**. Note that, in the following description, a direction in which the rotational phase of the cam **530** is changed in order of a first rotational phase R**1**, a second rotational phase R**2**, and a third rotational phase R**3** (a direction in which the cam **530** is rotated right-handedly (clockwise) in FIG. **4**) is defined as a direction in which the rotational phase of the cam **530** is increased.

As illustrated in FIG. **4**, three retention zones formed in a flat shape are provided on a cam surface of the cam **530** at intervals. More specifically, a first flat portion **530***a* constituting a first retention zone HD**1** is provided in a zone between the first rotational phase R**1** and the second rotational phase R**2**. A second flat portion **530***b* constituting a second retention zone HD**2** is provided in a zone between the third rotational phase R**3** and a fourth rotational phase R**4**. A third flat portion **530***c* constituting a third retention zone HD**3** is provided in a zone between a fifth rotational phase R**5** and a sixth rotational phase R**6**. Both ends of each of the retention zones HD**1** to HD**3** in a rotation direction of the cam have the same cam diameter, so that a part between the both ends is formed in a flat shape as described above.

Further, as illustrated in the cam diagram of FIG. **4**, respective lengths of the retention zones HD**1** to HD**3** are set so as to become longer in order of the first retention zone HD**1**<the second retention zone HD**2**<the third retention zone HD**3**. In other words, in a case where a rotational phase amount between the first rotational phase R**1** and the second rotational phase R**2** is assumed a reference amount, a rotational phase amount between the third rotational phase R**3** and the fourth rotational phase R**4** is set to be larger than the reference amount. Further, a rotational phase amount between the fifth rotational phase R**5** and the sixth rotational phase R**6** is set to be larger than the rotational phase amount between the third rotational phase R**3** and the fourth rotational phase R**4**.

In the meantime, as illustrated in FIG. **3** and the like, since a reaction force of the valve spring **24** acts on the output arm **321** of the variable mechanism portion **300**, a force to decrease the relative phase difference (the angle θ shown in FIG. **1**) between the input arm **311** and the output arm **321** acts. Accordingly, an axial force in a direction (a direction indicated by an arrow Lo in FIG. **2** and FIG. **3**) where the maximum lift amount of the intake valve **31** decreases acts on the slider gear **350** and the control shaft **340**. In the variable valve mechanism **600**, the roller **341** is being pressed against the cam surface of the cam **530** due to such an axial force.

When such an axial force acts on a zone in which the cam diameter gradually changes in the cam surface, a component force of the axial force is caused. The component force of the axial force acts as a force to rotate the cam **530** in a direction where the cam diameter decreases.

Here, as described above, the retention zones HD**1** to HD**3** in the cam surface of the cam **530** are each formed in a flat shape. Accordingly, as illustrated in FIG. **4**, a cam profile of each of the retention zones HD**1** to HD**3** has a shape in which the cam diameter gradually increases after the cam diameter gradually decreases as the rotational phase of the cam **530** changes in one direction, that is, a shape having a minimum point about the cam diameter.

Accordingly, in a rotational phase range of the cam **530** in the first retention zone HD**1** (in the zone between the first rotational phase R**1** and the second rotational phase R**2**), the cam diameter becomes shortest at a central phase (hereinafter referred to as a first central phase RS) serving as the minimum point, and the cam diameter gradually increases as it separates from the central phase. Similarly, also in a rotational phase range of the cam **530** in the second retention zone HD**2** (in the zone between the third rotational phase R**3** and the fourth rotational phase R**4**), the cam diameter becomes shortest at a central phase (hereinafter referred to as a second central phase RM) serving as the minimum point, and the cam diameter gradually increases as it separates from the central phase. Similarly, also in a rotational phase range of the cam **530** in the third retention zone HD**3** (in the zone between the fifth rotational phase R**5** and the sixth rotational phase R**6**), the cam diameter becomes shortest at a central phase (hereinafter referred to as a third central phase RL) serving as the minimum point, and the cam diameter gradually increases as it separates from the central phase. Note that, as illustrated in FIG. **4**, the cam diameter at the second central phase RM is larger than the cam diameter at the first central phase RS, and the cam diameter at the third central phase RL is larger than the cam diameter at the second central phase RM.

In each of the retention zones HD**1** to HD**3**, when the roller **341** of the control shaft **340** deviates from the cam surface at the central phase as the minimum point, the component force of the axial force acts to return the rotational phase of the cam back to the central phase. When the roller **341** makes contact with the cam surface of the retention zone due to the action of the component force, the rotational phase of the cam **530** is naturally directed toward the central phase in the retention zone, and the rotational phase of the cam **530** is stabilized at the central phase. On that account, a driving force to be generated from the motor **210** so as to retain the phase of the cam **530** can be made small at this time. For example, even if a holding current of the motor **210** is set to "0," the rotational phase of cam **530** can be retained at the central phase of the retention zone.

In the meantime, change zones (a first change zone constituting a zone between the second rotational phase R**2** and the third rotational phase R**3**, and a second change zone constituting a zone between the fourth rotational phase R**4** and the fifth rotational phase R**5**) formed so that the cam diameter continuously changes are formed between the retention zones HD**1** and HD**2** and between the retention zones HD**2** and HD**3** in the cam surface of the cam **530**. More specifically, the first and second change zones are formed so that the cam diameter gradually increases as the rotational phase of the cam **530** changes in one direction.

Even when the control shaft **340** (more specifically, the roller **341**) makes contact with the change zone of the cam **530**, the component force of the axial force acts so as to rotate the cam **530** in the direction where the cam diameter decreases. On that account, in order to pivot the cam **530** in a direction where the cam diameter increases, it is necessary to generate a relatively large driving force in the motor **210** so as to pivot the cam **530** against the component force of the axial force. In the meantime, when the cam **530** is pivoted in the direction where the cam diameter decreases, the component force of the axial force acts to assist for a rotation of the cam **530**, so that a driving force generated by the motor **210** can be restrained to be small.

Next will be described a relationship between the rotational phase of the cam **530** and a displacement amount of the control shaft **340**. As illustrated in FIG. **4**, when the rotational phase of the cam **530** is placed in the first retention zone HD**1** (between the first rotational phase R**1** and the second rotational phase R**2**), the displacement amount of the control shaft **340** is maintained at "0" due to the minimum point and the action of the component force of the axial force. Note that the displacement amount is a moving amount of the control shaft **340** from a reference position in the axial direction, and a position of the control shaft **340** at the time when the roller **341** makes contact with the cam surface of the cam **530** at the first central phase RS is the reference position.

When the rotational phase of the cam **530** is placed in the first change zone (between the second rotational phase R**2** and the third rotational phase R**3**), the displacement amount of the control shaft **340** gradually increases from a base point of "0" as the rotational phase of the cam **530** increases.

When the rotational phase of the cam **530** is placed in the second retention zone HD**2** (between the third rotational phase R**3** and the fourth rotational phase R**4**), the displacement amount of the control shaft **340** is maintained at a first displacement amount L**1** due to the minimum point and the action of the component force of the axial force. Here, the cam diameter in the second central phase RM is larger than the cam diameter in the first central phase RS, so the first displacement amount L**1** is an amount larger than "0."

When the rotational phase of the cam **530** is placed in the second change zone (between the fourth rotational phase R**4** and the fifth rotational phase R**5**), the displacement amount of the control shaft **340** gradually increases from the first displacement amount L**1** as a base point, as the rotational phase of the cam **530** increases.

When the rotational phase of the cam **530** is placed in the third retention zone HD**3** (between the fifth rotational phase R**5** and the sixth rotational phase R**6**), the displacement amount of the control shaft **340** is maintained at a second displacement amount L**2** due to the minimum point and the action of the component force of the axial force. Here, the cam diameter at the third central phase RL is larger than the cam diameter at the second central phase RM, so the second displacement amount L**2** is an amount larger than the first displacement amount L**1**.

Since the cam surface of the cam **530** has a cam profile based on the above cam diagram, the maximum lift amount VL of the intake valve **31** changes along with changes in the rotational phase of the cam **530** as follows.

As illustrated in FIG. **5**, as a rotational phase of the motor **210** increases, the rotational phase of the cam **530** gradually increases. When the rotational phase of the cam **530** is placed in the first retention zone HD**1** (between the first rotational phase R**1** and the second rotational phase R**2**), the displacement amount of the control shaft **340** is maintained at "0," so that the maximum lift amount VL of the intake valve **31** is maintained at a first lift amount VL**1**. Note that the first lift amount VL**1** is a minimum value of the maximum lift amount VL that is set to be variable.

Further, when the rotational phase of the cam **530** is placed in the first change zone (between the second rotational phase R**2** and the third rotational phase R**3**), the displacement amount of the control shaft **340** gradually increases as the rotational phase of the cam **530** increases, so that the maximum lift amount VL of the intake valve **31** gradually increases from the first lift amount VL**1** as a base point.

When the rotational phase of the cam **530** is placed in the second retention zone HD**2** (between the third rotational phase R**3** and the fourth rotational phase R**4**), the displacement amount of the control shaft **340** is maintained at the first displacement amount L**1**, so that the maximum lift amount VL of the intake valve **31** is maintained at a second lift amount VL**2**, which is larger than the first lift amount VL**1**.

Further, when the rotational phase of the cam **530** is placed in the second change zone (between the fourth rotational phase R**4** and the fifth rotational phase R**5**), the displacement amount of the control shaft **340** gradually increases as the rotational phase of the cam **530** increases, so that the maximum lift amount VL of the intake valve **31** gradually increases from the second lift amount VL**2** as a base point.

Then, when the rotational phase of the cam **530** is placed in the third retention zone HD**3** (between the fifth rotational phase R**5** and the sixth rotational phase R**6**), the displacement amount of the control shaft **340** is maintained at the second displacement amount L**2**, so that the maximum lift amount VL of the intake valve **31** is maintained at a third lift amount VL**3**, which is larger than the second lift amount VL**2**. Note that the third lift amount VL**3** is a maximum value of the maximum lift amount VL that is set to be variable.

In the variable valve mechanism **600** of the present embodiment, any of the first lift amount VL**1**, the second lift amount VL**2**, and the third lift amount VL**3** is selected as the target lift amount VLp of the intake valve **31** according to an engine operation state. Then, the maximum lift amount thus selected is retained. Hereby, the maximum lift amount VL of the intake valve **31** is changed selectively at three stages according to the engine operation state.

Next will be described an operation of the cam **530**. As illustrated in FIG. **6**, in a case where the control shaft **340** perpendicularly abuts with the third flat portion **530***c* constituting the third retention zone HD**3**, the component force of the axial force does not occur in an abutment portion between the cam **530** and the control shaft **340**, so the cam **530** does not rotate. Similarly, in terms of the second flat portion **530***b* or the first flat portion **530***a*, in a case where the control shaft **340** perpendicularly abuts therewith, the cam **530** does not rotate.

In the meantime, FIG. **7** illustrates a state where the control shaft **340** does not perpendicularly abut with the third flat portion **530***c* constituting the third retention zone HD**3**. Note that, also in terms of the second flat portion **530***b* or the first flat portion **530***a*, the control shaft **340** may not perpendicularly abut therewith.

Incidentally, such a state where the control shaft **340** does not perpendicularly abut may occur, for example, in a case where, as a result of a rotational phase control of the cam **530**, a rotational phase K at the time when the maximum lift amount VL is retained deviates from the third central phase RL, the second central phase RM, or the first central phase RS. Further, such a state may also occur in a case where the rotation center CR of the roller **341** or the rotation center C of the cam **530** deviates from the extended line of the central axis CL of the control shaft **340**.

As illustrated in FIG. **7**, in a case where the control shaft **340** does not perpendicularly abut with the third flat portion **530***c* constituting the third retention zone HD**3**, a component force F**2** of the axial force F occurs in the abutment portion between the cam **530** and the control shaft **340**, so that a running torque RT caused due to the component force F**2** acts on the cam **530**. Similarly, also in terms of the second flat portion **530***b* or the first flat portion **530***a*, in a case where the control shaft **340** does not perpendicularly abut therewith, the running torque RT caused due to the component force F**2** acts on the cam **530**.

Since a magnitude of an axial force F periodically changes according to changes in a compression amount of the valve spring **24** along with opening/closing operations of the intake valve **31**, a magnitude of the running torque RT also periodically changes in accordance with such periodic changes in the axial force F. The cam **530** swings due to such periodic changes in the running torque RT.

Here, as the compression amount of the valve spring **24** is larger, that is, as the maximum lift amount VL set to be variable is larger, a maximum value of the axial force F becomes larger. Further, as the maximum value of the axial force F becomes larger, a maximum value of the component force F**2** also becomes larger. Accordingly, a swing amount at the time when the cam **530** swings in the above mode increases, as a retained maximum lift amount VL is larger and the axial force F is hereby larger. Accordingly, in a case where the maximum lift amount VL is relatively large, the swing amount of the cam **530** might increase excessively. In some cases, the control shaft **340** (more strictly, the roller **341**) that should abut with the cam surface in the retention zone of the cam **530** deviates from the retention zone, which might cause the control shaft **340** to abut with the cam surface in the change zone. Note that, in a feedback control to control the rotational phase of the cam **530**, as the swing amount of the cam **530** is larger, the increase and decrease of a feedback controlled amount related to the rotational phase control becomes remarkable. On that account, large hunting occurs in the rotational phase of the cam **530** to be feedback-controlled, which may promote the swing of the cam **530**, so that the swing amount might easily increase.

When the control shaft **340** deviates from the retention zone of the cam **530** as such, it is difficult to obtain an effect to retain the maximum lift amount VL by use of the retention zone, for example, that is, an effect to be able to retain the maximum lift amount VL at a constant value even if current application to the motor **210** is stopped as described above. This accordingly causes inconvenience that power consumption of the motor **210** increases, and so on.

In this regard, in the present embodiment, respective lengths of the retention zones HD**1** to HD**3** are set so as to become longer in order of the first retention zone HD**1**<the second retention zone HD**2**<the third retention zone HD**3**, as described above. That is, respective lengths of the retention zones HD**1** to HD**3** are set so that a retention zone with a larger maximum lift amount VL to be retained becomes longer, and a retention zone in which a swing amount at the time when the cam **530** swings due to the axial force F transmitted from the control shaft **340** easily increases has a longer length. Accordingly, even if the swing amount of the cam **530** becomes large, the abutment portion between the control shaft **340** and the cam **530** is hard to deviate from the retention zone.

In the meantime, when the retention zone is set to be long, a necessary rotational phase amount of the cam **530** to change the abutment portion between the control shaft **340** and the cam **530** from the retention zone to the change zone becomes large. Accordingly, a change velocity to change the maximum lift amount VL decreases.

In this regard, in the present embodiment, a retention zone with a larger maximum lift amount VL to be retained is set to have a longer length, whereas a retention zone with a smaller maximum lift amount VL to be retained is set to have a shorter length. Accordingly, in comparison with a case where all the retention zones (the first retention zone HD**1**, the second retention zone HD**2**, and the third retention zone HD**3**) are set to have sufficiently long lengths in accordance with a maximum value of the swing amount of the cam **530**, a retention zone with a smaller maximum lift amount VL to be retained has a smaller necessary rotational phase amount of the cam **530** to change the abutment portion from the retention zone to the change zone. Accordingly, it is possible to appropriately restrain a decrease in a change velocity to change the maximum lift amount VL.

Further, as illustrated in FIG. **4**, the cam profile of each of the retention zones HD**1** to HD**3** has a shape in which the cam diameter gradually increases after the cam diameter gradually decreases as the rotational phase of the cam **530** changes in one direction, that is, a shape having a minimum point about the cam diameter. Accordingly, in a case where a change amount of the cam diameter relative to a rotational phase change of the cam **530** in the retention zone is maintained and the retention zone is made longer, the change amount of the cam diameter in the retention zone increases. Accordingly, when the rotational phase of the cam **530** is changed from the retention zone to the change zone so as to change the maximum lift amount VL toward an increase side, it is necessary to generate more torque from the motor **210**, which increases power consumption of the motor **210**.

In this regard, in the present embodiment, a retention zone with a smaller maximum lift amount VL to be retained is set to have a shorter length, as described above. Accordingly, it is possible to restrain the increase in power consumption of the motor **210** due to lengthening of the retention zone.

As described above, according to the above embodiment, it is possible to yield the following effects. (1) Respective lengths of the retention zones in which to retain the maximum lift amount VL are set so that a retention zone with a larger maximum lift amount VL to be retained becomes longer. Accordingly, even if the swing amount of the cam **530** becomes large, the abutment portion between the control shaft **340** and the cam **530** is hard to deviate from the retention zone.

(2) A retention zone with a larger maximum lift amount VL to be retained is set to have a longer length, whereas a retention zone with a smaller maximum lift amount VL to be retained is set to have a shorter length. Accordingly, it is possible to appropriately restrain a decrease in a change velocity to change the maximum lift amount VL. Further, it is possible to restrain an increase in power consumption of the motor **210**.

(3) The cam surface of the cam **530** is provided with the first retention zone HD**1** and the second retention zone HD**2** so as to be adjacent to the first change zone. Further, the second retention zone HD**2** and the third retention zone HD**3** are provided so as to be adjacent to the second change zone. Accordingly, the maximum lift amount VL changed by use of the first change zone can be retained in the first retention zone HD**1** and the second retention zone HD**2** adjacent to the first change zone. Similarly, the maximum lift amount VL changed by use of the second change zone can be retained in the second retention zone HD**2** and the third retention zone HD**3** adjacent to the second change zone.

(4) The variable valve mechanism **600** is a mechanism in which the cam diameter of the cam **530** increases so as to increase the displacement amount of the control shaft **340**, thereby increasing the maximum lift amount VL of the intake valve **31**. The variable valve mechanism **600** is formed so that the cam diameter in the first and second change zones continuously changes and the cam surface in each of the retention zones HD**1** to HD**3** is formed to be a flat surface. According to such a configuration, since the maximum lift amount VL continuously changes in the first and second change zones, sudden changes in the intake-air amount along with changes in the maximum lift amount VL can be restrained. Accordingly, sudden changes in engine power torque due to the sudden changes in the intake-air amount can be restrained, for example.

Further, the cam surface in each of the retention zones HD**1** to HD**3** is formed to be a flat surface. Accordingly, when the control shaft **340** makes contact with the cam surface in each of the retention zones HD**1** to HD**3**, the rotational phase of the cam **530** is naturally directed toward the minimum point (the central phase) in the retention zone, and the maximum lift amount VL is retained at an amount according to the cam diameter at the minimum point (the central phase). Accordingly, with such a simple structure in which the cam **530** includes a cam surface in which the cam diameter continuously changes and a cam surface formed to be a flat surface, it is possible to embody change and retention of the maximum lift amount VL.

Note that the above embodiment can be modified as follows. —The variable valve mechanism **600** is a mechanism that changes the maximum lift amount of the intake valve **31** at three stages, but the number of stages to change the maximum lift amount can be modified appropriately.

The shape of the cam **530** is one example, and the cam **530** may have other shapes provided that the control shaft **340** can move in the axial direction. —A flat part is provided in the cam surface so as to provide a minimum point in the cam diameter, but such a minimum point may be provided in other shapes.

A flat part is provided in the cam surface so as to retain the maximum lift amount VL, and hereby, a minimum point in the cam diameter is provided. Alternatively, a zone in which the cam diameter is constant and does not change may be provided in the cam surface so as to retain the maximum lift amount VL.

FIG. **8** illustrates a cam **630** in such a modification. A cam diagram illustrating a relationship between a rotational phase of the cam **630** and a displacement amount of a control shaft **340** is illustrated on a right side in FIG. **8**, and a cam profile (an actual shape of the cam **630**) formed based on the cam diagram is illustrated on a left side in FIG. **8**. Further, the cam **530** of the above embodiment and the cam **630** of the modification are different in cam diagrams and cam profiles of retention zones in which to retain a maximum lift amount VL, that is, cam diagrams and cam profiles of a first retention zone HD**1**, a second retention zone HD**2**, and a third retention zone HD**3**. The following describes the cam **630** mainly about such different points.

As illustrated in FIG. **8**, change zones formed so that a cam diameter continuously changes are also formed in a cam surface of the cam **630**. More specifically, change zones (a first change zone constituting a zone between a second rotational phase R**2** and a third rotational phase R**3**, and a second change zone constituting a zone between a fourth rotational phase R**4** and a fifth rotational phase R**5** in FIG. **8**) in which a displacement amount of the control shaft **340** linearly increases as the cam diameter gradually increases in one direction are provided in the cam surface of the cam **630**.

Further, the cam surface of the cam **630** is provided with three retention zones in each of which the cam diameter is constant and the displacement amount of the control shaft **340** is constant. More specifically, a first retention portion **630***a* constituting a first retention zone HD**1** is provided in a zone between a first rotational phase R**1** and the second rotational phase R**2**. A cam surface of the first retention portion **630***a* is formed so that the cam diameter is constant and does not change, and as illustrated in the cam diagram, the displacement amount of the control shaft **340** is set to "0" in the first retention zone HD**1**. Accordingly, in the first retention zone HD**1**, the maximum lift amount VL is retained at the first lift amount VL**1**.

Further, a second retention portion **630***b* constituting a second retention zone HD**2** is provided in a zone between the third rotational phase R**3** and the fourth rotational phase R**4**. A cam surface of the second retention portion **630***b* is also formed so that the cam diameter is constant and does not change, and the cam diameter in the second retention portion **630***b* is larger than the cam diameter in the first retention portion **630***a*. As illustrated in the cam diagram, the displacement amount of the control shaft **340** is retained at the first displacement amount L**1** in a zone of the second retention portion **630***b*. Accordingly, in the second retention zone HD**2**, the maximum lift amount VL is retained at the second lift amount VL**2**.

Further, a third retention portion **630***c* constituting a third retention zone HD**3** is provided in a zone between the fifth rotational phase R**5** and a sixth rotational phase R**6**. A cam surface of the third retention portion **630***c* is also formed so that the cam diameter is constant and does not change, and the cam diameter in the third retention portion **630***c* is larger than the cam diameter in the second retention portion **630***b*. As illustrated in the cam diagram, the displacement amount of the control shaft **340** is retained at the second displacement amount L**2** in a zone of the third retention portion **630***c*. Accordingly, in the third retention zone HD**3**, the maximum lift amount VL is retained at the third lift amount VL**3**.

Even in such a modification, since the maximum lift amount VL changes continuously in the first and second change zones, sudden changes of the intake-air amount along with changes of the maximum lift amount VL can be restrained. Accordingly, sudden changes in engine power torque due to the sudden changes in the intake-air amount can be restrained, for example.

Further, in this modification, since the cam diameter in each of the retention zones HD**1** to HD**3** is formed so as to be constant, the displacement amount of the control shaft **340** does not change in each of the retention zones HD**1** to HD**3**. Accordingly, the maximum lift amount VL in each of the retention zones HD**1** to HD**3** is retained at an amount according to the cam diameter thus formed to be constant. Accordingly, even in this modification, with such a simple structure in which the cam **630** includes a cam surface in which the cam diameter continuously changes and a cam surface formed so that the cam diameter is constant, it is possible to embody change and retention of the maximum lift amount VL.

Also in the cam **630** of the modification, respective lengths of the retention zones HD**1** to HD**3** are set so as to become longer in order of the first retention zone HD**1**<the second retention zone HD**2**<the third retention zone HD**3**, as illustrated in the cam diagram of FIG. **8**. In other words, in a case where a rotational phase amount between the first rotational phase R**1** and the second rotational phase R**2** is assumed a reference amount, a rotational phase amount between the third rotational phase R**3** and the fourth rotational phase R**4** is set to be larger than the reference amount. Further, a rotational phase amount between the fifth rotational phase R**5** and the sixth rotational phase R**6** is set to be larger than the rotational phase amount between the third rotational phase R**3** and the fourth rotational phase R**4**.

As illustrated in FIG. **9**, in a state where the control shaft **340** abuts with the third retention portion **630***c* constituting the third retention zone HD**3**, the cam diameter is constant, so a tangent S at an abutment portion between the cam **630** and the control shaft **340** is perpendicular to a central axis CL of the control shaft **340**. Accordingly, the aforementioned component force F**2** of the axial force F does not occur, so that the cam **630** does not rotate. Similarly, in terms of the second retention portion **630***b* or the first retention portion **630***a*, if the tangent S is perpendicular to the central axis CL of the control shaft **340**, the cam **630** does not rotate in a state where the control shaft **340** abuts therewith.

In the meantime, FIG. **10** illustrates a state where the control shaft **340** abuts with the third retention portion **630***c* constituting the third retention zone HD**3**, but the tangent S is not perpendicular to the central axis CL of the control shaft **340**. Note that, also in terms of the second retention portion **630***b* or the first retention portion **630***a*, the tangent S may not be perpendicular to the central axis CL of the control shaft **340**.

Incidentally, the state where the tangent S is not perpendicular to the central axis CL of the control shaft **340** may be caused in a case where a rotation center C of the cam **630** or a rotation center CR of a roller **341** deviates from an extended line of the central axis CL of the control shaft **340**.

As illustrated in FIG. **10**, in a case where the tangent S is not perpendicular to the central axis CL of the control shaft **340**, the aforementioned component force F**2** of the axial force F occurs in the abutment portion between the cam **630** and the control shaft **340**, so that a running torque RT caused due to the component force F**2** acts on the cam **630**. Similarly, in terms of the second retention portion **630***b* or the first retention portion **630***a*, in a case where the tangent S is not perpendicular to the central axis CL of the control shaft **340**, the running torque RT caused due to the component force F**2** acts on the cam **630**. Accordingly, the cam **630** having the retention zones in which the cam diameter is constant may also have a problem similar to the cam **530**, and the control shaft **340** (more strictly, the roller **341**) that should abut with the cam surface in the retention zone of the cam **630** may deviate from the retention zone, thereby causing the control shaft **340** to abut with the cam surface in the change zone.

In this regard, also in this modification, respective lengths of the retention zones HD**1** to HD**3** are set so as to become longer in order of the first retention zone HD**1**<the second retention zone HD**2**<the third retention zone HD**3**, similarly to the above embodiment. Accordingly, it is possible to obtain the same effect as in the above embodiment. That is, respective lengths of the retention zones HD**1** to HD**3** are set so that a retention zone with a larger maximum lift amount VL to be retained becomes longer, and a retention zone in which a swing amount at the time when the cam **630** swings due to the axial force F transmitted from the control shaft **340** easily increases has a longer length. Accordingly, even if the swing amount of the cam **630** becomes large, the abutment portion between the control shaft **340** and the cam **630** is hard to deviate from the retention zone.

Further, in this modification, a retention zone with a larger maximum lift amount VL to be retained is set to have a longer length, whereas a retention zone with a smaller maximum lift amount VL to be retained is set to have a shorter length. Accordingly, in comparison with a case where all the retention zones (the first retention zone HD**1**, the second retention zone HD**2**, and the third retention zone HD**3**) are set to have sufficiently long lengths in accordance with a maximum value of the swing amount of the cam **630**, a retention zone with a smaller maximum lift amount VL to be retained has a smaller necessary rotational phase amount of the cam **630** to change the abutment portion from the retention zone to the change zone. Accordingly, similarly to the above embodiment, it is possible to appropriately restrain a decrease in a change velocity to change the maximum lift amount VL.

The variable mechanism portion **300** is a mechanism that can change the maximum lift amount and the valve opening period of the intake valve **31**. Alternatively, the variable mechanism portion **300** may be a mechanism that can change only the maximum lift amount. —The variable mechanism portion **300** is provided in a valve train system of the intake valve **31**, but may be provided in a valve train system of the exhaust valve **41**.

The following describes a technical idea that can be understood from the above embodiment and its modification. In the above variable valve mechanism for an internal combustion engine, a rotational phase of the cam may be feedback-controlled so as to become a target rotational phase according to a target maximum lift amount.

According to the configuration above, even if the swing of the cam is promoted due to the feedback control and a swing amount of the cam might easily increase, the effects as described in the above embodiment and its modification can be obtained. Accordingly, it is possible to restrain the abutment portion between the control shaft and the cam from deviating from the retention zone due to the increase in the swing amount of the cam.

What is claimed is:

1. A variable valve mechanism for an internal combustion engine, the variable valve mechanism comprising:

a control shaft configured to be displaced in an axial direction of the control shaft, the control shaft being configured to change a maximum lift amount of an engine valve of the internal combustion engine according to displacement of the control shaft in the axial direction; and

a cam including a cam surface of the cam, the cam surface configured to abut with the control shaft, the cam being configured to displace the control shaft in the axial direction due to rotation of the cam, the cam surface including change zones and retention zones, the cam surface in the change zones being configured to change the maximum lift amount along with the rotation of the cam, the cam surface in the retention zones being configured to retain the maximum lift amount along with the rotation of the cam, respective lengths of the retention zones in a rotation direction of the cam being set such that respective length of the retention zones in the rotation direction increases as the maximum lift amount retained by the retention zones increases.

2. The variable valve mechanism according to claim **1**, wherein

in the cam surface, the retention zones are provided so as to be adjacent to the change zones.

3. The variable valve mechanism according to claim **1**, wherein:

the cam surface in the change zones is configured such that a cam diameter of the cam continuously increases along with the rotation of the cam such that the maximum lift amount increases along with the rotation of the cam; and

the cam surface in the retention zones is a flat surface.

4. The variable valve mechanism according to claim **1**, wherein:

the cam surface in the change zones is configured such that a cam diameter of the cam continuously increases along with the rotation of the cam such that the maximum lift amount increases along with the rotation of the cam; and

the cam surface in the retention zones is configured such that the cam diameter is constant.

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